CALCULATION OF HEAT LOSSES FROM NIT-ROURKELA'S SWIMMING POOL AND A STUDY ON EVAPORATIVE LOSSES USING MATLAB

A REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY (CHEMICAL ENGINEERING)

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CERTIFICATE

This is to certify that that the work in this thesis report entitled "**Calculation of heat losses from NIT Rourkela's swimming pool and a study on evaporative losses using MATLAB"** submitted by **Srinidhi Sharma** in partial fulfilment of the requirements for the degree of Bachelor of Technology in Chemical Engineering, Session 2007-2011 in the department of Chemical Engineering, National Institute of Technology, Rourkela, is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this report has not been submitted to any other University /Institute for the award of any degree.

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Date: 07/05/2011

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ABSTRACT

The objective of this project is to calculate heat losses from NIT Rourkela's swimming pool and to conduct a study on evaporative losses using MATLAB. A swimming pool is an open system from which continuous heat and mass transfer occurs to and from its environment. One of the major losses of heat from a swimming pool happens because of evaporation. In this project, temperatures of the concerned swimming pool water and the ambient air were recorded for a period of 26 days starting from 2 Nov 2010 to 27 Nov 2010. On each day readings were taken 6 times on a regular basis. Then, relative humidity data for Rourkela, India was collected for 5 days from 23 Nov 2010 to 27 Nov 2010. So, along with vapour pressure data of water, the different heat losses, namely, convective, evaporative and radiation heat losses were calculated for the 5 days. Also, graphs were plotted between evaporative losses per unit area of the swimming pool vs Time and total heat losses per unit area vs time. The results thus obtained are discussed. Then, a study was conducted using MATLAB to see the variation of evaporative losses with relative humidity and ambient air temperature. It was found that for a given relative humidity, evaporative loss increases with increase in ambient air temperature.

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NOMENCLATURE

Q_c = convective heat loss per m^2 of the swimming pool area.(W/m^2)

Q_e = evaporative heat loss per m^2 of the swimming pool area. (W/m^2)

Q_r = radiation heat loss per m^2 of the swimming pool area. (W/m^2)

h = convective heat transfer co-efficient (W/m^2K)

ΔT = Difference between swimming pool water and ambient air temperature (°C)

P = vapour pressure of water at the gas temperature (kPa)

p = partial pressure of water vapour in air at the gas temperature (kPa)

T_p= recorded pool water temperature (°C)

T_a= recorded ambient air temperature (°C)

σ = Stefan Boltzmann constant

ε = emissivity of water

RH= Relative humidity (%)

CHAPTER 1

INTRODUCTION

Swimming pool water exposed to the atmosphere is like an open system. Both mass and heat transfer take place between the water and the surrounding environment. Pool water becomes colder when energy is withdrawn through heat losses. Heat losses occur primarily at the surface of the water through evaporation, conduction and convection, and thermal radiation. Relatively little heat is lost to the ground.

Evaporative losses occur when the water at the surface of the pool is converted into vapor and carried away in the air. Besides decreasing the pool temperature, evaporation also results in significant loss of water and pool chemicals. Evaporation is increased by high wind-speeds, high pool water temperature, high air temperature, and low relative humidity.

Conduction and convection losses are closely linked with evaporative losses and occur when heat from the pool surface is transferred to the cooler surrounding air. Conduction and convection losses increase with high wind-speeds, low outside air temperatures, and high pool temperature. Radiant heat losses occur when a warm pool radiates heat directly into the cooler sky. These losses increase when the sky is clear, the relative humidity is low, and the pool temperature is high.

CHAPTER 2

THEORY AND LITERATURE REVIEW

2.1 Heat losses

In considering the actual heat losses from open pools, the periods of daylight and darkness differ sufficiently to make advisable their separate treatment. At night there are conductive losses to the ground (though under certain conditions the ground may actually give heat to the water), radiant losses to the surroundings, evaporative losses (which can be extremely severe), and convective losses to the air above the pool [1]. Conductive losses from a swimming pool heated to 24 deg C are small enough to be neglect.

Convective heat losses are evaluated by the formula:

$$Q_c = h\Delta T$$

Qc varies considerably if the normal wind pattern is altered by trees, buildings, or even by eddies set up by high pool curbs. The variation is further affected by the orientation of an oblong pool relative to the wind direction. In general, any protection from a direct wind sweep causes a substantial reduction in the convective coefficient h.

The evaporation losses may be high also, and in arid regions where the average relative humidity is 20 per cent or less they may be extremely severe.

To obtain evaporative losses in MKS system, we have

$$Q_e = 16.3h(P-p)$$

[2]

Evaporation losses are often considerably higher during daylight hours than during the night. The air, warmed by the sun, generally has considerably less relative humidity, and evaporation is thus greater. In addition to this, the air velocity is apt to be higher and the swimmers cause turbulence in the pool water itself, tending to increase the effective film temperature well above normal wet-bulb temperature for the air-to-water interface [1].

Radiant heat losses to the ambient environment are expressed as:

$$Q_r=\sigma\varepsilon(T_p^4-T_a^4)$$

where 'ε' is the emittance of water in the infrared (0.95), 'σ' is the Stefan-Boltzmann constant (5.669×10^{-8} $(W/m^2)/K^4$), T_p is the pool temperature and T_a is the ambient temperature.

2.2 Relative humidity

Relative humidity is a measurement of the amount of water vapor in a mixture of air and water vapor. It is most commonly defined as the partial pressure of water vapor in the air-water mixture, given as a percentage of the saturated vapor pressure under those conditions. The relative humidity of air thus changes not only with respect to the absolute humidity (moisture content) but also temperature and pressure, upon which the saturated vapor pressure depends. Relative humidity is often used instead of absolute humidity in situations where the rate of water evaporation is important, as it takes into account the variation in saturated vapor pressure [3].

2.3 Antoine equation

Antoine equation is a vapor pressure equation and describes the relation between vapor pressure and temperature for pure components. The Antoine equation is derived from the Clausius-Clapeyron relation [4].

$$\log_{10} p = A - \frac{B}{C + T}.$$

where *p* is the vapor pressure, *T* is temperature and *A*, *B* and *C* are component-specific constants.

For water, A= 8.071 ; B= 1730.63 ; C=233.426 [5].

2.4 MATLAB

MATLAB (matrix laboratory) is a numerical computing environment and fourth-generation programming language. Developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing capabilities. An additional package, Simulink adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems [6].

2.5 Solar pool rings

In outdoor swimming pools, in order to reduce the heat losses, solar pool rings are generally used. Their shape is like a circular disc. Each of them rest on top of the swimming pool surface and pull in the sunrays to keep the pool warm. They are passive heating systems. Essentially, each disc is made from two sheets or layers of U.V resistant vinyl. The first layer is usually clear or of light colour. The top layer gets exposed to the air. It serves two purposes. It directs the sun's power to the lower layer. The second being, it acts like an insulation layer trapping heat to help keep the water warm.

The next layer is blue in colour. It can take large amounts of sunlight and turn it into heat. It not only gets the pool heated during the day, it also retains the heat during cool evenings. In order to cover the pool and keep their formation, the rings are held together by magnets around their outside edges. This allows them to stay together. The magnets also help improve the clearness of water by lowering water hardness [7].

Fig 2.5.1 Solar pool rings

CHAPTER 3

PROJECT WORK

3.1 Air and Pool water Temperature readings

The air temperature and the swimming pool water temperature were measured 6 times a day, for 26 days in the month of November from 2-Nov-2010 to 27-Nov-2010 at **NIT Rourkela's swimming pool**. The daily readings were taken at 6 AM, 6:40 AM, 7:30 AM, 9 AM, 2 PM and 4 PM. The readings are tabulated below (in the order of water temperature/ air temperature). The temperatures in the table are in Celsius.

Date	6 AM	6:40 AM	7:30 AM	9 AM	2 PM	4 PM
02-Nov	25/21	25/22	24/23	25/30	26/31	25/22
03-Nov	25/22	24/22	23/22	25/29	25/32	24/21
04-Nov	27/25	25/23	24/23	26/28	27/32	26/22
05-Nov	24/23	24/21	27/26	25/27	28/31	25/21
06-Nov	25/22	24/21	26/24	26/28	29/30	25/22
07-Nov	25/21	24/23	24/29	23/29	28/31	27/22
08-Nov	24/22	23/22	26/24	26/21	27/25	28/23
09-Nov	25/23	26/24	28/28	28/25	29/31	29/28
10-Nov	25/22	24/25	30/27	26/28	30/32	28/27
11-Nov	24/21	26/24	26/24	27/25	29/31	30/31
12-Nov	25/22	27/23	25/23	27/26	30/28	28/30
13-Nov	27/23	28/22	24/22	26/24	30/30	27/25
14-Nov	26/25	27/25	28/24	30/28	31/30	28/29
15-Nov	27/25	27/26	28/27	30/28	30/32	27/25
16-Nov	27/26	27/27	27/26	28/26	30/31	28/27
17-Nov	26/25	26/27	28/27	28/27	29/30	27/28
18-Nov	27/25	25/26	28/27	29/27	32/35	27/25
19-Nov	27/26	28/27	28/26	30/31	30/32	28/26
20-Nov	28/26	28/27	30/28	30/31	30/32	28/26
21-Nov	28/26	25/26	30/26	30/31	30/32	28/27
22-Nov	25/16	25/16	25/16	29/28	30/31	28/30
23-Nov	25/23	26/24	28/16	28/27	31/32	27/29
24-Nov	25/24	26/25	28/29	30/31	30/29	26/24
25-Nov	24/26	27/25	26/25	28/27	30/32	28/26
26-Nov	27/29	28/26	30/31	29/28	32/35	29/30
27-Nov	26/28	28/27	28/27	30/31	32/35	28/30

Table 3.1 Air and pool water temperature readings

3.2 Dimensions and capacity of the swimming pool

The pool is 50 m in length and 22 m in width. The depth of the pool is 1.83 m for half of its length. It then decreases gradually from 1.83 m to 1.05 m for the other half of its length. From its geometry, at full capacity the swimming pool can hold 1732.5 m^3 of water. A schematic diagram of the swimming pool is given below.

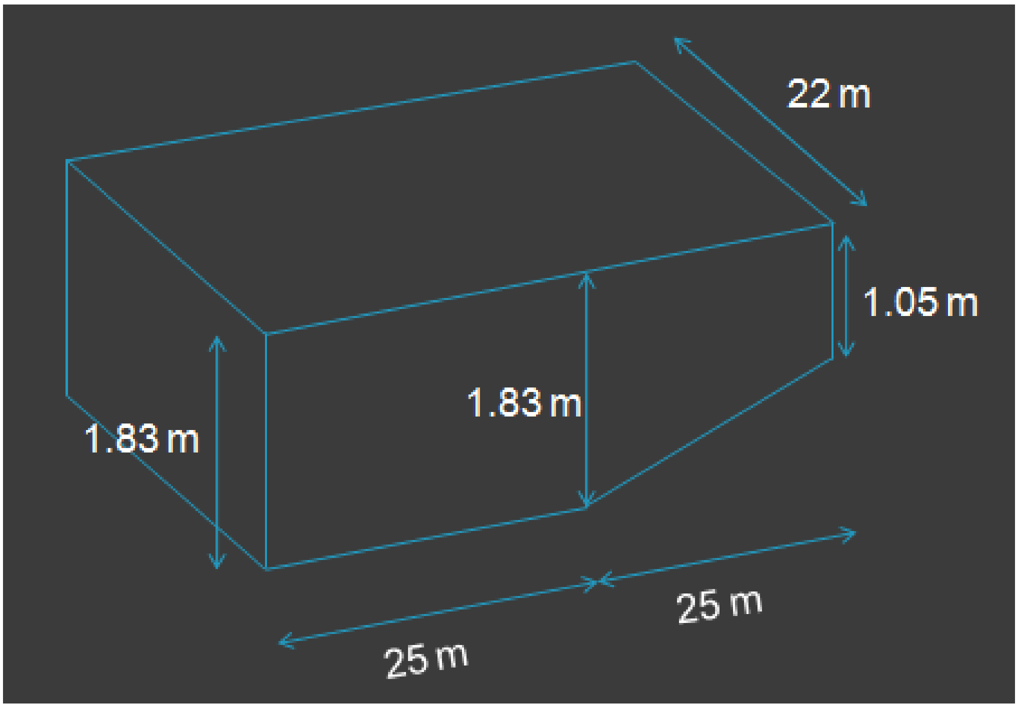

Fig 3.2.1 Schematic diagram of NIT Rourkela's swimming pool

$$\text{Capacity} = 1732.5 \ m^3$$

3.3 Heat loss Calculations

Three types of heat losses were evaluated at NIT Rourkela's swimming pool, namely, convective, evaporation and radiation losses. Firstly, relative humidity data was collected (sourced online) for 5 days in the month of November, 23-Nov-2010 to 27-Nov-2010.

Using the vapour pressure data of water at the ambient air temperature, partial pressures of water vapour in the air were calculated (in KPa) for different readings of temperature. Calculations for these 5 days were done for readings taken 4 times a day, at 6 AM, 9 AM, 2 PM and 4 PM respectively.

Assumptions made for the calculations are as follows:

1. The convective heat transfer co-efficient was assumed to be 10 W/m^2K.
2. Emissivity of water was taken to be **0.95.**
3. Radiation losses were evaluated only when the swimming pool temperature was higher than the ambient air temperature.
4. Convective losses are negative indicate that heat is being gained by the swimming pool, given the comparatively higher ambient air temperature.

Formula for convective heat loss:

$$Q_c=h\Delta T$$

Formula for evaporative heat loss:

$$Q_e=16.3h(P-p)$$

(Aman Dang et al., 1986)

Stefan-Boltzmann's law for radiation losses:

$$Q_r=\sigma\varepsilon(T_p^4-T_a^4)$$

The exposed surface area of the swimming pool= 1100 m^2

Formula for Relative humidity:

$$RH=(p/P)*100$$

So, based on the assumptions and considerations made and after using the formulae given above, the required variables (heat losses) were calculated. The values found are for one meter square area of the swimming pool's exposed surface.

The observations and the results of calculations are tabulated below.

The temperatures (water/air-in that order tabulated) are in Celsius. Relative humidity is expressed in percentage. The vapour pressures of water and partial pressures of water vapour are in KPa (kilopascals) units. The convective, evaporative, radiation heat losses are in W/m^2 units. The total heat loss is Watts.

23 Nov-2010

Time	Temperature(°C)	Relative humidity(%)	Vapor pressure of water (KPa)	Partial pressure of water vapour(KPa)
6:00 AM	25/23	91	2.808	2.555
9:00 AM	28/27	64	3.564	2.280
2:00 PM	31/32	35	4.754	1.66
4:00 PM	27/29	56	4.005	2.242

Time	$Q_e(W/m^2)$	$Q_c(W/m^2)$	$Q_r(W/m^2)$	Total loss per $m^2(W/m^2)$	Total loss for entire area (W)
6:00 AM	41.193	20	11.28	72.482	79731.03
9:00 AM	209.135	30	5.846	244.98	269480.301
2:00 PM	503.686	-10	-	493.6863	543054.93
4:00 PM	287.238	-20	-	267.2386	293962.46

Table 3.2- Observations and results for 23 Nov 2010

24 Nov-2010

Time	Temperature(°C)	Relative humidity(%)	Vapor pressure of water (KPa)	Partial pressure of water vapour(KPa)
6:00 AM	25/24	94	2.983	2.804
9:00 AM	30/31	69	4.492	3.099
2:00 PM	30/29	33	4.005	1.321
4:00 PM	26/24	50	2.983	1.491

Time	$Q_e(W/m^2)$	$Q_c(W/m^2)$	$Q_r(W/m^2)$	Total loss per $m^2(W/m^2)$	Total loss for entire area (W)
6:00 AM	29.173	10	5.673	44.846	49331.644
9:00 AM	226.980	-10	-	216.980	238678.836
2:00 PM	437.386	10	5.964	453.350	498685.150
4:00 PM	243.114	20	11.408	274.518	301970.151

Table 3.3- Observations and results for 24 Nov 2010

<u>25 Nov-2010</u>

Time	Temperature(°C)	Relative humidity(%)	Vapor pressure of water (KPa)	Partial pressure of water vapour(KPa)
6:00 AM	24/26	88	3.36	2.956
9:00 AM	28/27	65	3.564	2.316
2:00 PM	30/32	35	4.754	1.663
4:00 PM	28/26	49	3.36	1.646

Time	$Q_e(W/m^2)$	$Q_c(W/m^2)$	$Q_r(W/m^2)$	Total loss per $m^2(W/m^2)$	Total loss for entire area (W)
6:00 AM	65.721	-20	-	45.7216	50293.76
9:00 AM	203.326	10	5.846	219.172	241090.049
2:00 PM	503.686	-20	-	483.686	532054.93
4:00 PM	279.316	20	11.634	310.951	342046.946

Table 3.4- Observations and results for 25 Nov 2010

26 Nov-2010

Time	Temperature(°C)	Relative humidity(%)	Vapor pressure of water (KPa)	Partial pressure of water vapour(KPa)
6:00 AM	27/29	82	4.005	3.284
9:00 AM	29/28	61	3.779	2.305
2:00 PM	32/35	38	5.622	2.136
4:00 PM	29/30	59	4.242	2.502

Time	$Q_e(W/m^2)$	$Q_c(W/m^2)$	$Q_r(W/m^2)$	Total loss per $m^2(W/m^2)$	Total loss for entire area (W)
6:00 AM	117.506	-20	-	97.506	107257.37
9:00 AM	240.231	10	5.905	256.136	281749.781
2:00 PM	568.159	-30	-	538.159	591975.252
4:00 PM	283.492	-10	-	273.492	300842.146

Table 3.5- Observations and results for 26 Nov 2010

27 Nov-2010

Time	Temperature(°C)	Relative humidity(%)	Vapor pressure of water (KPa)	Partial pressure of water vapour(KPa)
6:00 AM	26/28	87	3.779	3.287
9:00 AM	30/31	76	4.492	3.413
2:00 PM	32/35	40	5.622	2.248
4:00 PM	28/30	55	4.242	2.333

Time	Q_e(W/m^2)	Q_c(W/m^2)	Q_r(W/m^2)	Total loss per m^2(W/m^2)	Total loss for entire area (W)
6:00 AM	80.077	-20	-	60.077	66084.711
9:00 AM	175.727	-10	-	165.727	182299.744
2:00 PM	549.831	-30	-	519.831	571814.76
4:00 PM	311.150	-20	-	291.150	320265.77

Table 3.6- Observations and results for 27 Nov 2010

3.4 Evaporative heat loss per m^2 vs Time (00 hrs) plots

23 Nov 2010

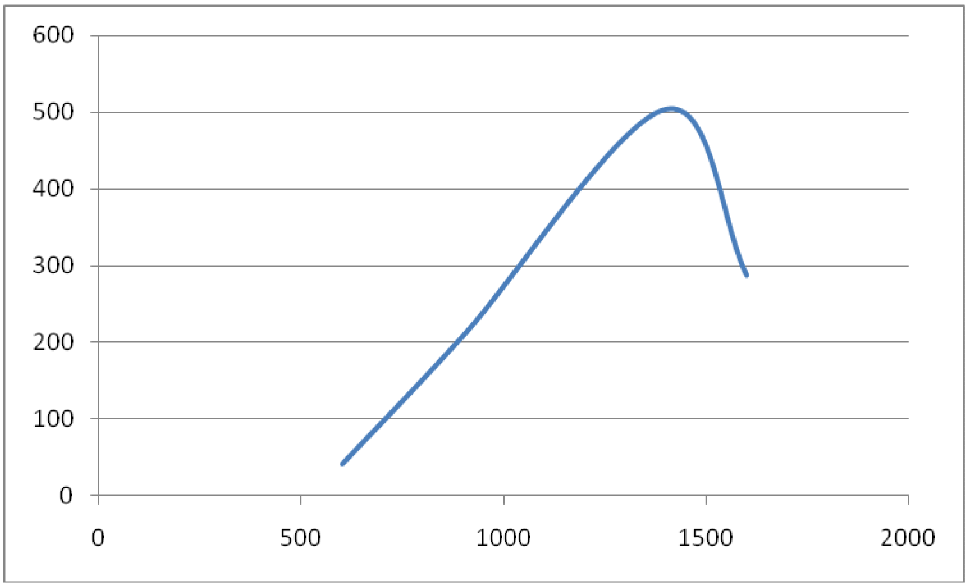

Fig 3.4.1- (y)-evaporative heat loss per m^2 vs (x)-time (00 hrs) for 23 Nov 2010

24 Nov 2010

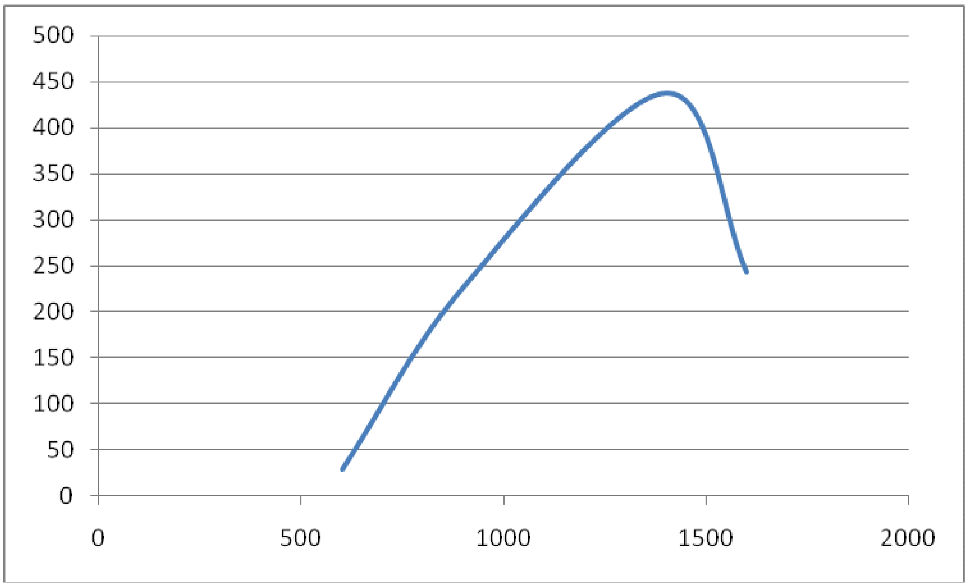

Fig 3.4.2- (y)-evaporative heat loss per m^2 vs (x)-time (00 hrs) for 24 Nov 2010

25 Nov 2010

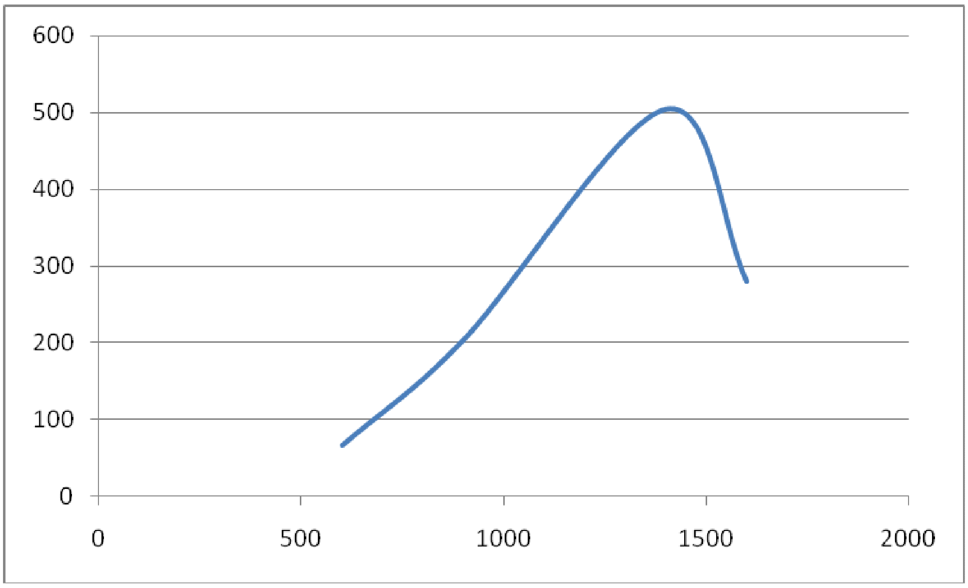

Fig 3.4.3- (y)-evaporative heat loss per m^2 vs (x)-time (00 hrs) for 25 Nov 2010

26 Nov 2010

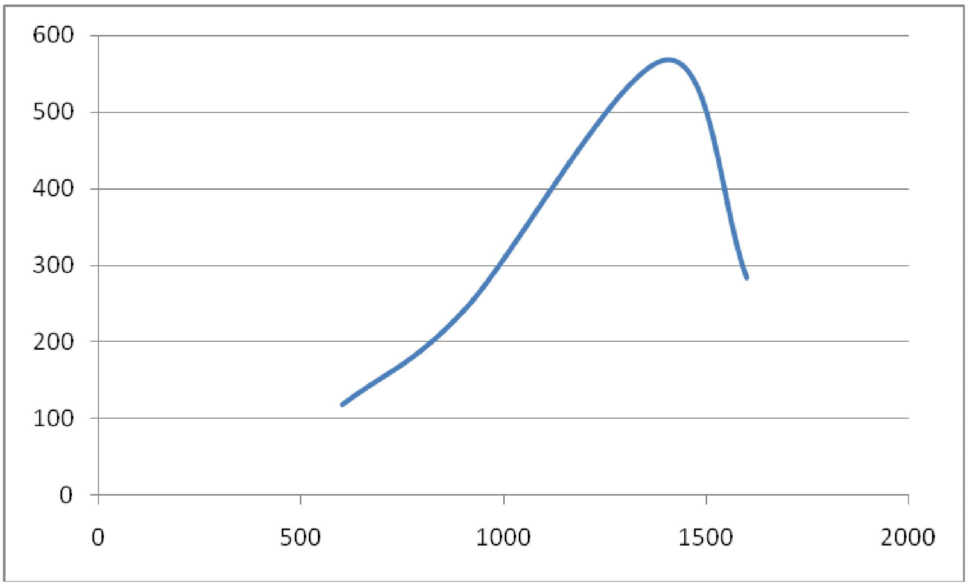

Fig 3.4.4- (y)-evaporative heat loss per m^2 vs (x)-time (00 hrs) for 26 Nov 2010

27 Nov 2010

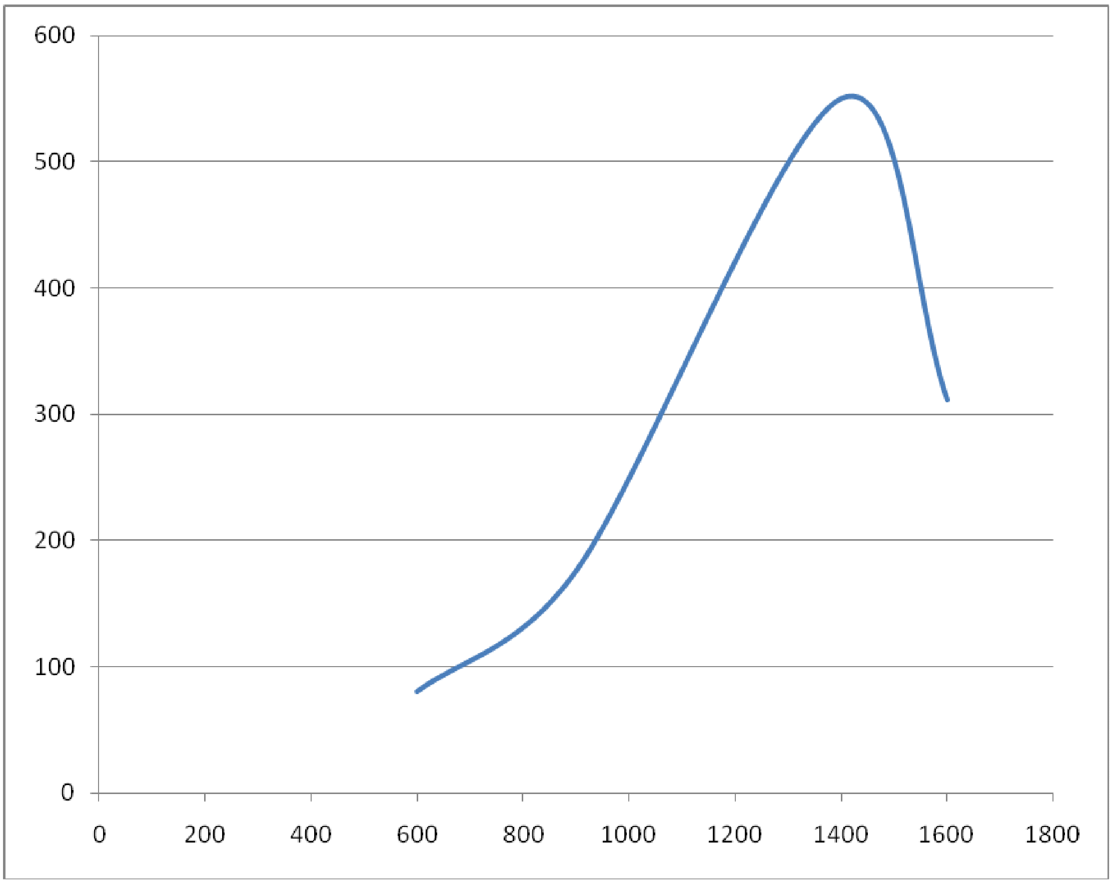

Fig 3.4.5- (y)-evaporative heat loss per m^2 vs (x)-time (00 hrs) for 27 Nov 2010

3.5 Total heat loss per m^2 vs Time (00 hrs) plots

<u>23 Nov 2010</u>

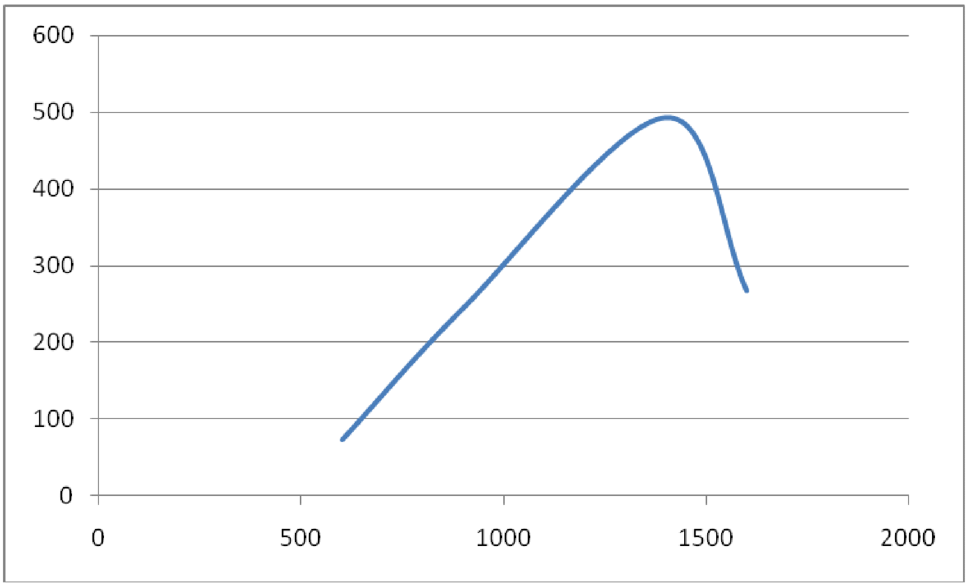

Fig 3.5.1- (y)-Total heat loss per m^2 vs (x)-time (00 hrs) for 23 Nov 2010

<u>24 Nov 2010</u>

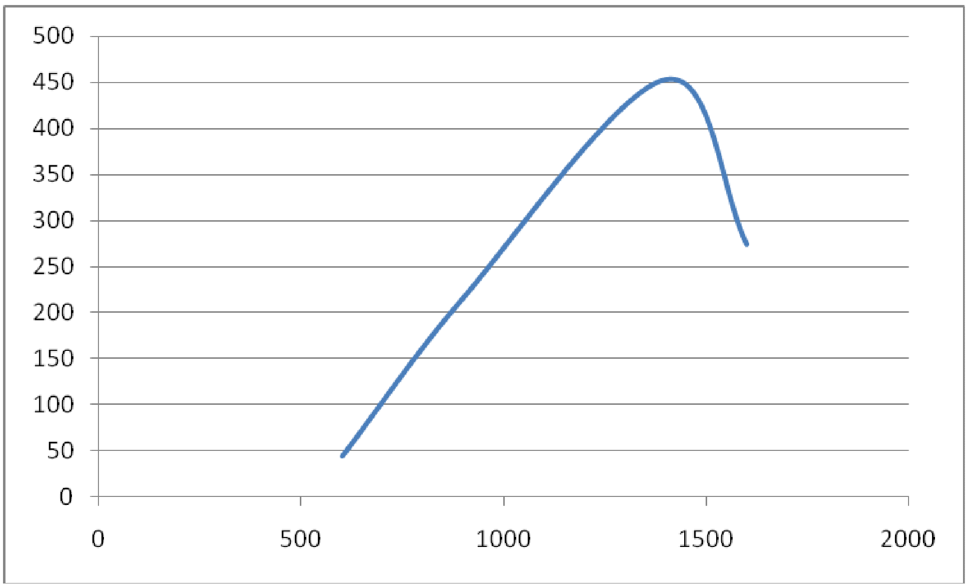

Fig 3.5.2- (y)-Total heat loss per m^2 vs (x)-time (00 hrs) for 24 Nov 2010

25 Nov 2010

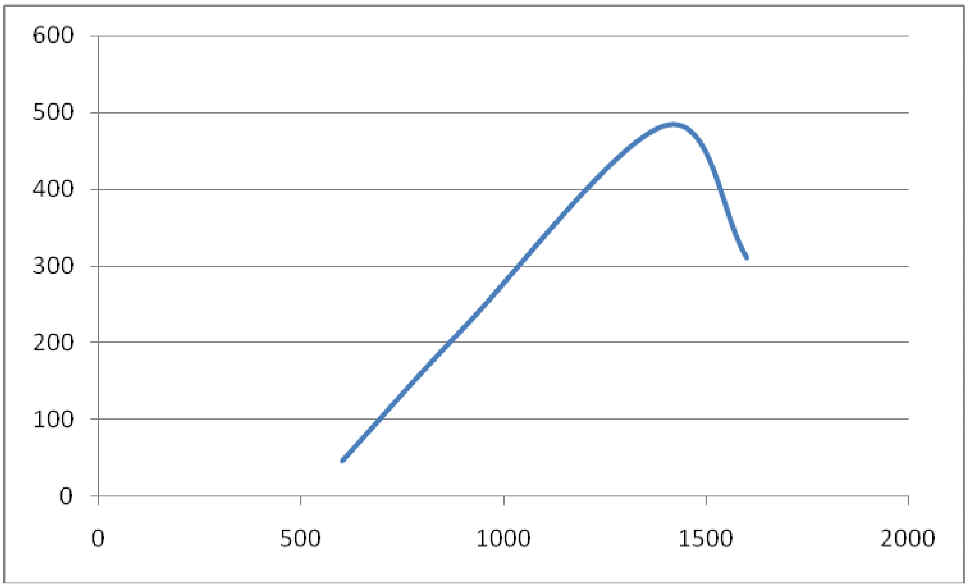

Fig 3.5.3- (y)-Total heat loss per m^2 vs (x)-time (00 hrs) for 25 Nov 2010

26 Nov 2010

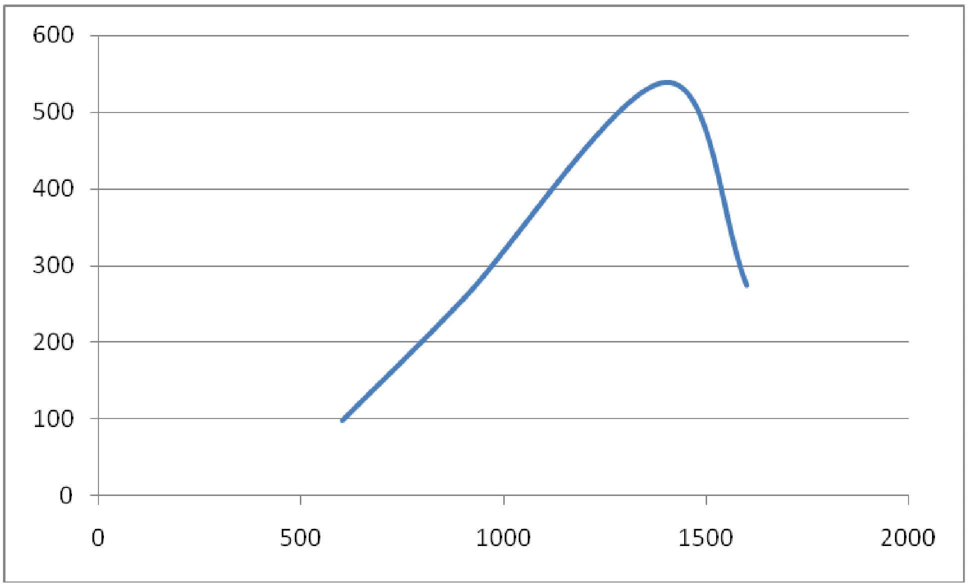

Fig 3.5.4- (y)-Total heat loss per m^2 vs (x)-time (00 hrs) for 26 Nov 2010

27 Nov 2010

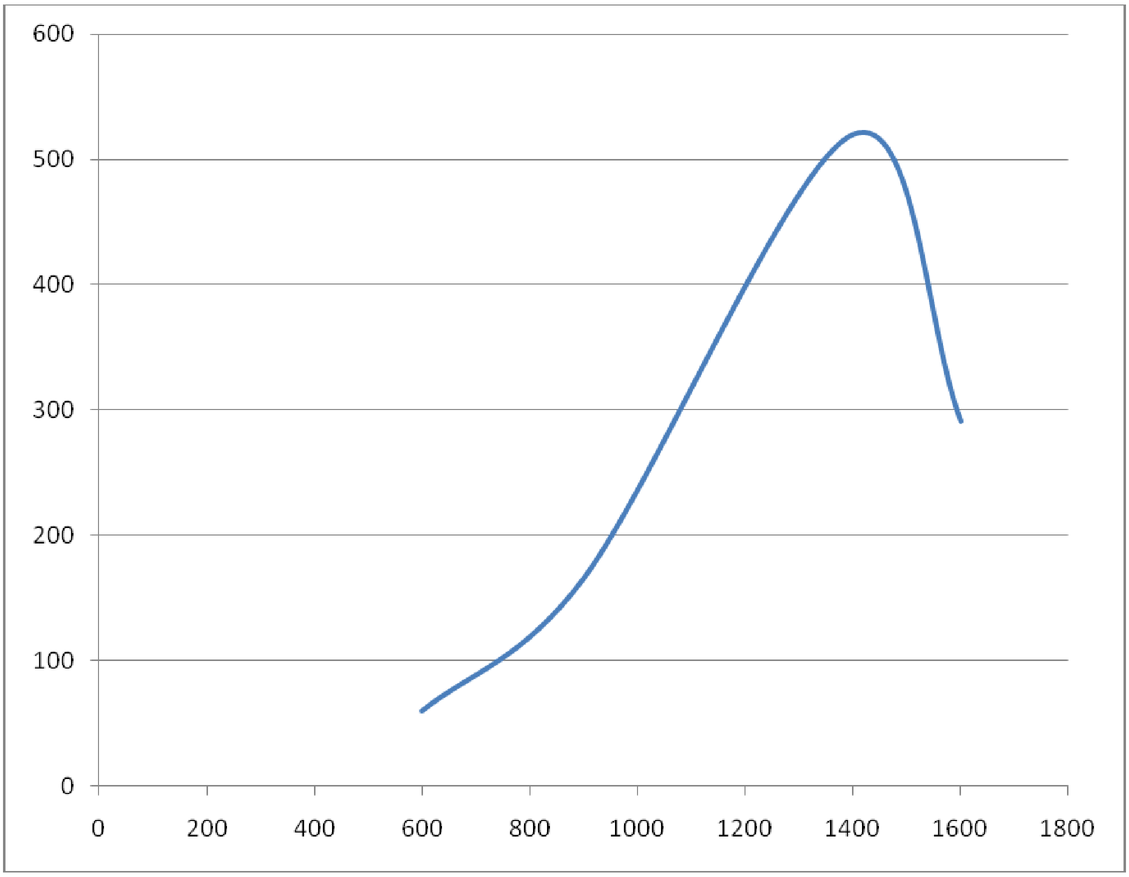

Fig 3.5.5- (y)-Total heat loss per m^2 vs (x)-time (00 hrs) for 27 Nov 2010

CHAPTER 4

A STUDY ON EVAPORATIVE LOSSES USING MATLAB

Based on the calculations done in the previous chapter, it is obvious that evaporative loss is the major contributor to the total heat loss from an exposed swimming pool. Evaporative loss depends largely on relative humidity and temperature of the ambient atmosphere. In this study, I've tried to study that dependence of evaporative loss and interpret the results using MATLAB.

4.1 Programming steps

1. A desired range of values were inputted for ambient air temperature (15°C -30°C in this case).
2. Saturation vapour pressure of water was calculated using Antoine equation.
3. The pressure values which were obtained in torr units were converted to kilopascal units for convenience.
4. Relative humidity values were inputted in percentage form ranging from 5% to 95% at an incremental step of 5%.
5. In an iterative loop, partial pressure values of the vapour at ambient air temperature were calculated for all the temperature-relative humidity combinations.
6. In the same iterative loop, evaporative losses were calculated for all the temperature-relative humidity combinations.
7. The saturation pressure of water's variation with temperature was plotted.
8. At a given ambient air temperature, the variation of evaporative loss with relative humidity was plotted.
9. Similar plots were plotted for all the temperature values considered.

4.2 MATLAB Code

```
% STUDY OF EVAPORATIVE LOSSES IN AN OUTDOOR SWIMMING POOL

for i=1:16
    x(i)=i+14;
end
for i=1:16
m(i)=8.071-(1730.63)/(233.426+x(i));     % Antoine equation for water
P(i)= 10^m(i);          % 'P' is the saturation vapor pressure of water
end

figure (1);
plot(x,P); grid on; % Plots pool temperature with saturation vapor pressure

% Temperature is in Celsius and pressure is in torr units

for i=1:16
    P(i)=P(i)*(101.325/760);
end          % Converts pressure values to kilopascal units

% Relative humidity data input

for i=1:19
    R(i)=5*(i);
end

% Partial pressure of water vapor calculations

for i=1:16
for j=1:19
    p(i,j)=R(j)*P(i)/100;
    q(i,j)=16.3*10*(P(i)-p(i,j));  % Calculates evaporative losses
end
end

i=1:16;
figure (2);
plot(x(i),q(i,1)); grid on;
title('5% Relative humidity', 'fontsize',12);

figure (3);
plot(x(i),q(i,2)); grid on;
title('10% Relative humidity', 'fontsize',12);

figure (4);
plot(x(i),q(i,3)); grid on;
title('15% Relative humidity', 'fontsize',12);

figure (5);
plot(x(i),q(i,4)); grid on;
title('20% Relative humidity', 'fontsize',12);

figure (56);
plot(x(i),q(i,5)); grid on;
title('25% Relative humidity', 'fontsize',12);
```

```
figure (7);
plot(x(i),q(i,6)); grid on;
title('30% Relative humidity', 'fontsize',12);

figure (8);
plot(x(i),q(i,7)); grid on;
title('35% Relative humidity', 'fontsize',12);

figure (9);
plot(x(i),q(i,8)); grid on;
title('40% Relative humidity', 'fontsize',12);

figure (10);
plot(x(i),q(i,9)); grid on;
title('45% Relative humidity', 'fontsize',12);

figure (11);
plot(x(i),q(i,10)); grid on;
title('50% Relative humidity', 'fontsize',12);

figure (12);
plot(x(i),q(i,11)); grid on;
title('55% Relative humidity', 'fontsize',12);

figure (13);
plot(x(i),q(i,12)); grid on;
title('60% Relative humidity', 'fontsize',12);

figure (14);
plot(x(i),q(i,13)); grid on;
title('65% Relative humidity', 'fontsize',12);

figure (15);
plot(x(i),q(i,14)); grid on;
title('70% Relative humidity', 'fontsize',12);

figure (16);
plot(x(i),q(i,15)); grid on;
title('75% Relative humidity', 'fontsize',12);

figure (17);
plot(x(i),q(i,16)); grid on;
title('80% Relative humidity', 'fontsize',12);

figure (18);
plot(x(i),q(i,17)); grid on;
title('85% Relative humidity', 'fontsize',12);

figure (19);
plot(x(i),q(i,18)); grid on;
title('90% Relative humidity', 'fontsize',12);

figure (20);
plot(x(i),q(i,19)); grid on;
title('95% Relative humidity', 'fontsize',12);
```

4.4 Results

- Evaporative heat loss values are tabulated below in W/m^2.

Relative humidity(%) Ambient temperature(°C)	5	10	15	20	25	30
15	262.6842	248.8587	235.0332	221.2077	207.3822	193.5568
16	280.1325	265.3887	250.6449	235.9011	221.1573	206.4134
17	298.5865	282.8714	267.1563	251.4412	235.7262	220.0111
18	318.0946	301.3528	284.611	267.8692	251.1273	234.3855
19	338.7075	320.8807	303.054	285.2273	267.4006	249.5739
20	360.4773	341.5049	322.5324	303.5599	284.5874	265.6149
21	383.4586	363.2766	343.0946	322.9125	302.7305	282.5485
22	407.7077	386.2494	364.7911	343.3328	321.8745	300.4162
23	433.283	410.4786	387.6742	364.8699	342.0655	319.2611
24	460.2449	436.0215	411.7981	387.5747	363.3513	339.1279
25	488.6563	462.9376	437.2188	411.5001	385.7813	360.0626
26	518.5821	491.2883	463.9945	436.7007	409.4069	382.1131
27	550.0893	521.1372	492.1852	463.2331	434.281	405.329
28	583.2476	552.5503	521.8531	491.1559	460.4586	429.7614
29	618.1288	585.5957	553.0626	520.5295	487.9964	455.4633
30	654.8072	620.3437	585.8801	551.4166	516.953	482.4895

Table 4.4.1 Evaporative losses (W/m^2) for 5% to 30% relative humidity

Relative humidity(%) Ambient Temperature(°C)	35	40	45	50	55	60
15	179.7313	165.9058	152.0803	138.2548	124.4293	110.6039
16	191.6696	176.9258	162.182	147.4382	132.6944	117.9505
17	204.296	188.5809	172.8659	157.1508	141.4357	125.7206
18	217.6437	200.9019	184.16	167.4182	150.6764	133.9346
19	231.7472	213.9205	196.0938	178.2671	160.4404	142.6137
20	246.6424	227.6699	208.6974	189.7249	170.7524	151.7799
21	262.3664	242.1844	222.0024	201.8203	181.6383	161.4563
22	278.9579	257.4996	236.0413	214.583	193.1247	171.6664
23	296.4568	273.6524	250.848	228.0437	205.2393	182.4349
24	314.9044	290.681	266.4576	242.2342	218.0108	193.7873
25	334.3438	308.6251	282.9063	257.1875	231.4688	205.75
26	354.8193	327.5255	300.2317	272.9379	245.6441	218.3503
27	376.3769	347.4248	318.4728	289.5207	260.5686	231.6165
28	399.0641	368.3669	337.6696	306.9724	276.2752	245.5779
29	422.9302	390.3971	357.864	325.3309	292.7978	260.2647
30	448.026	413.5624	379.0989	344.6354	310.1718	275.7083

Table 4.4.2 Evaporative losses (W/m^2) for 35% to 60% relative humidity

Relative humidity(%) Ambient Temperature (°C)	65	70	75	80	85	90	95
15	96.7784	82.9529	69.1274	55.3019	41.4764	27.651	13.8255
16	103.2067	88.4629	73.7191	58.9753	44.2315	29.4876	14.7438
17	110.0055	94.2905	78.5754	62.8603	47.1452	31.4302	15.7151
18	117.1928	100.4509	83.7091	66.9673	50.2255	33.4836	16.7418
19	124.787	106.9602	89.1335	71.3068	53.4801	35.6534	17.8267
20	132.8074	113.835	94.8625	75.89	56.9175	37.945	18.9725
21	141.2742	121.0922	100.9102	80.7281	60.5461	40.3641	20.182
22	150.2081	128.7498	107.2915	85.8332	64.3749	42.9166	21.4583
23	159.6306	136.8262	114.0218	91.2175	68.4131	45.6087	22.8044
24	169.5639	145.3405	121.1171	96.8937	72.6703	48.4468	24.2234
25	180.0313	154.3125	128.5938	102.875	77.1563	51.4375	25.7188
26	191.0565	163.7628	136.469	109.1752	81.8814	54.5876	27.2938
27	202.6645	173.7124	144.7603	115.8083	86.8562	57.9041	28.9521
28	214.8807	184.1834	153.4862	122.789	92.0917	61.3945	30.6972
29	227.7316	195.1986	162.6655	130.1324	97.5993	65.0662	32.5331
30	241.2448	206.7812	172.3177	137.8541	103.3906	68.9271	34.4635

Table 4.4.3 Evaporative loss (W/m^2) for 65% to 95% relative humidity

4.5 Graphs

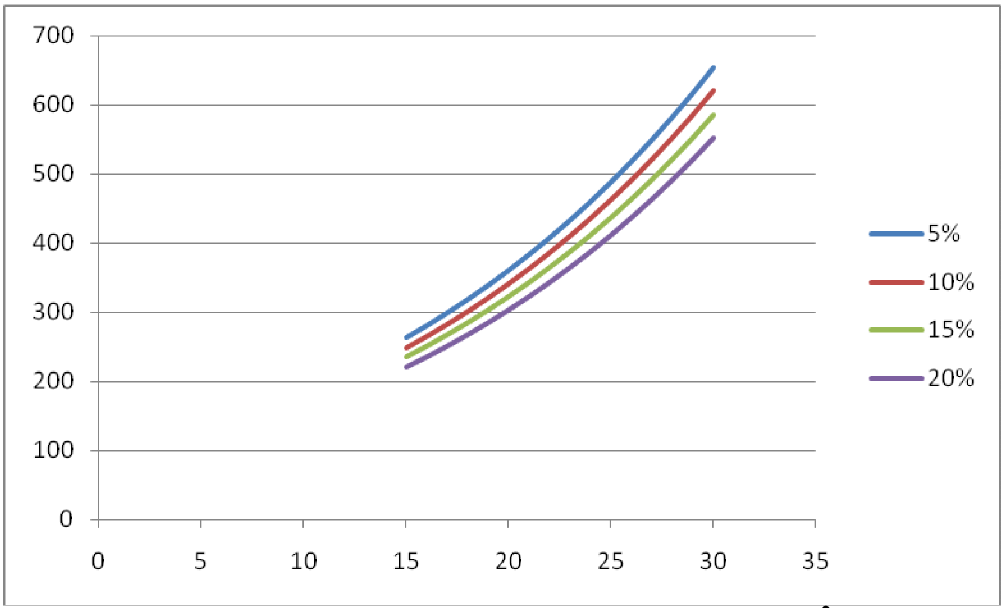

Fig 4.5.1 (y)-Evaporative loss per unit area (W/m^2) vs (x)-Ambient temperature(°C) for relative humidity from 5% to 20%

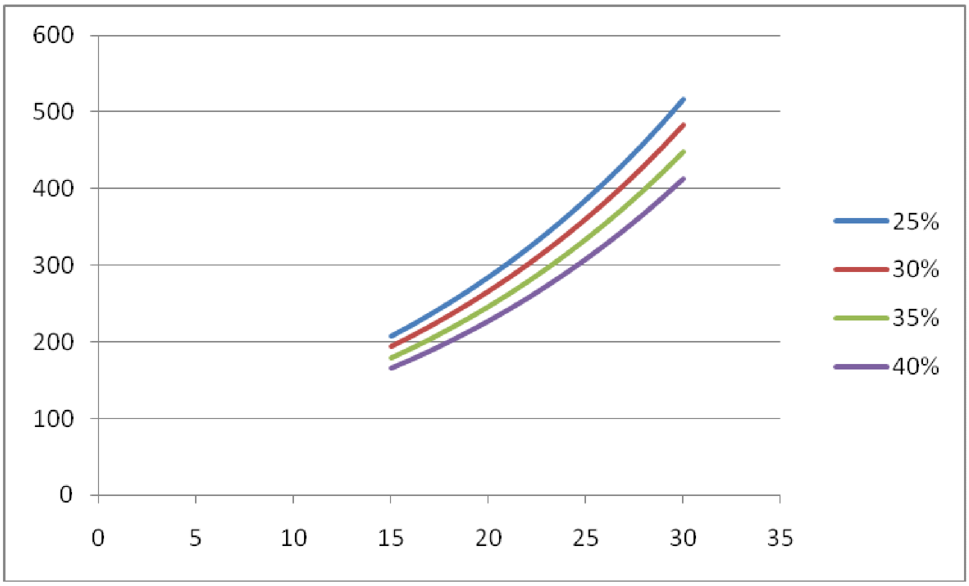

Fig 4.5.2 (y)-Evaporative loss per unit area (W/m^2) vs (x)-Ambient temperature(°C) for relative humidity from 25% to 40%

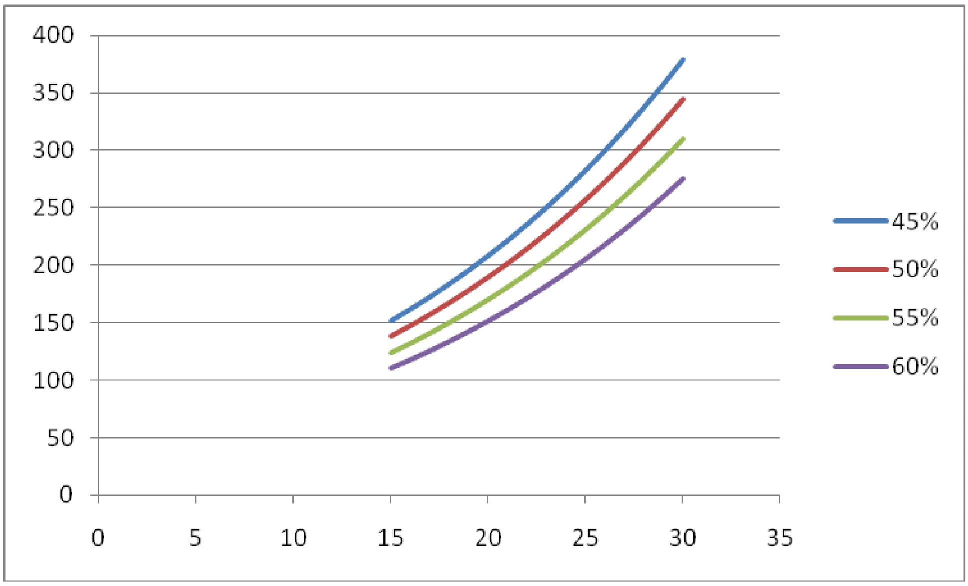

Fig 4.5.3 (y)-Evaporative loss per unit area (W/m^2)
vs (x)-Ambient temperature(°C) for relative humidity from 45% to 60%

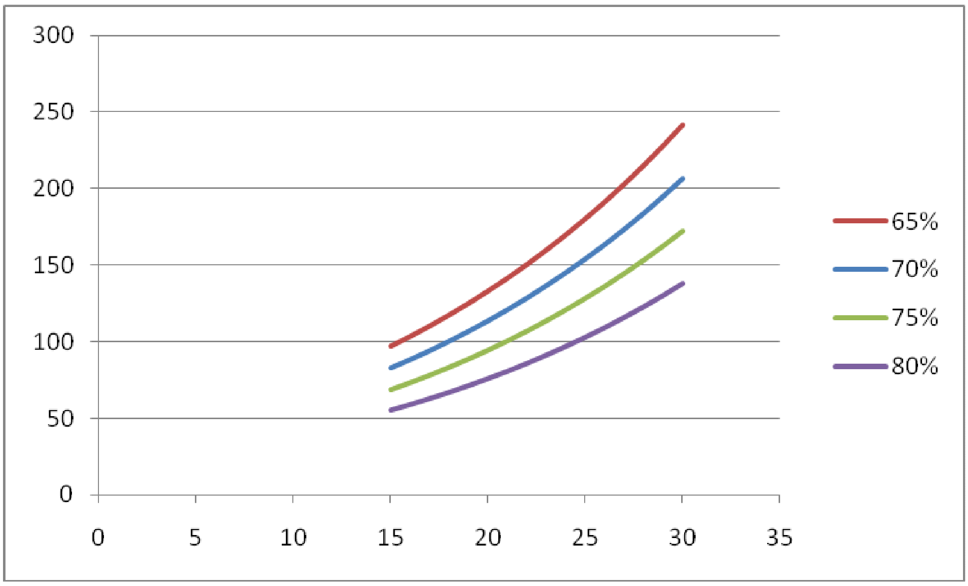

Fig 4.5.4 (y)-Evaporative loss per unit area (W/m^2)
vs (x)-Ambient temperature(°C) for relative humidity from 65% to 80%

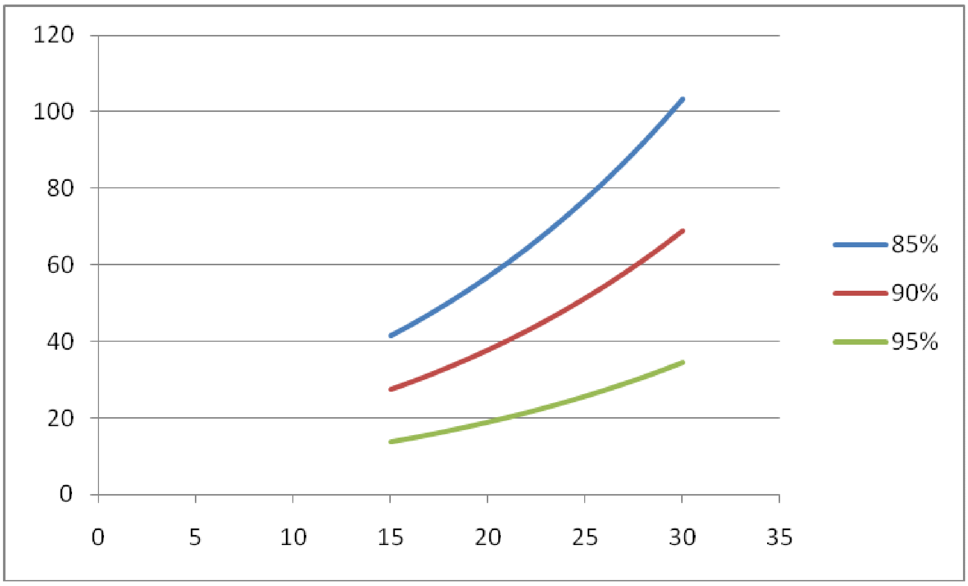

Fig 4.5.5 (y)-Evaporative loss per unit area (W/m^2)
vs (x)-Ambient temperature(°C) for relative humidity from 85% to 95%

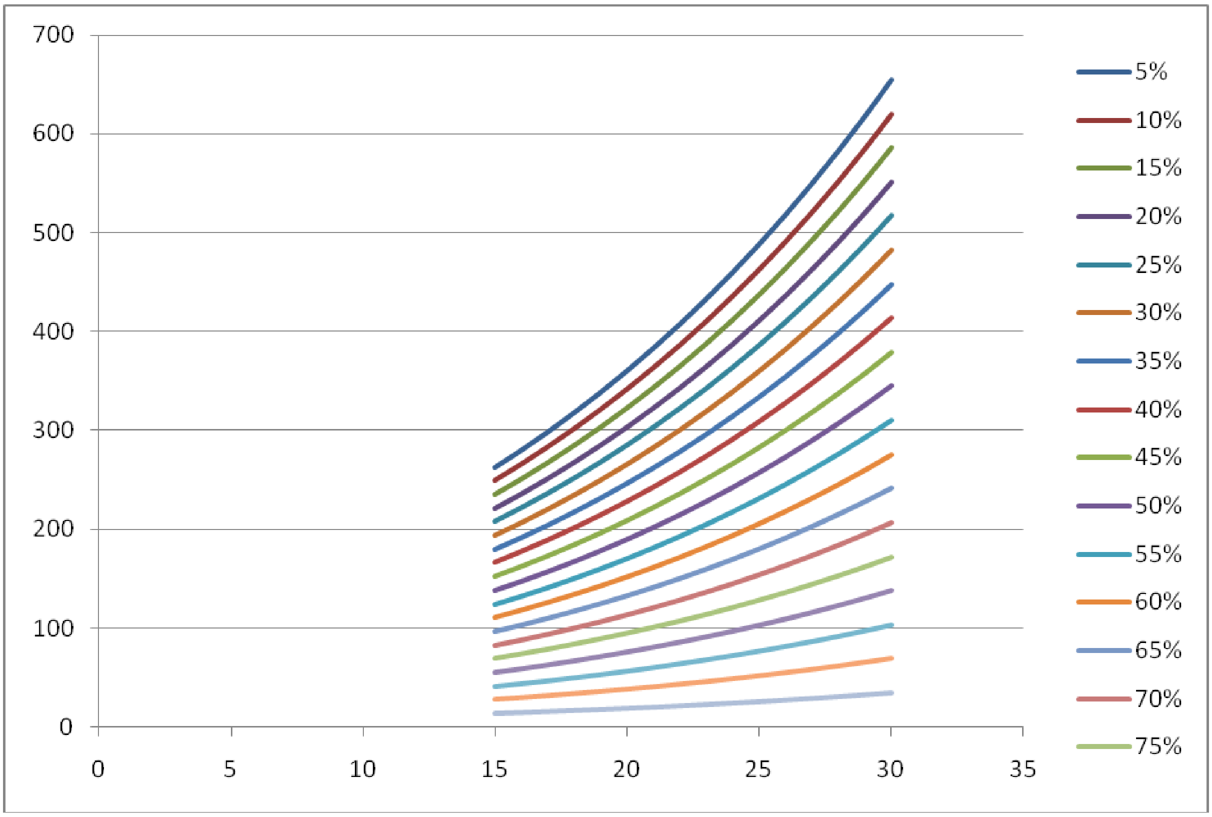

Fig 4.5.6 (y)-Evaporative loss per unit area (W/m^2)
vs (x)-Ambient temperature(°C) for relative humidity from 5% to 95%

CHAPTER 5

DISCUSSIONS

- It is evident from the calculation results and graphs, that evaporative loss per m^2 of swimming pool water surface is least during early morning hours. This is because, highest humidity prevails early in the morning, as per weather forecasts. So, during that time, the difference between the vapour pressure of water and the partial pressure of water vapour in air is the least.
- But as the day progresses, it was observed that humidity decreased and reached its everyday lowest point at 2 PM in the afternoon. This seemed to be the driest point in the day's timeline. Also, the pressure difference was maximum at 2 PM in the afternoon. This resulted in the peak evaporative loss at 2 PM on every other day observed.
- The highest and lowest pool water temperatures were found to be 32°C and 24°C respectively. The highest and lowest ambient air temperatures were recorded to be 35°C and 16°C respectively. The highest and lowest evaporative heat losses per m^2 were 568.16 and 29.173 W/m^2 respectively.
- It is observed from the calculation results and graphical plots that the total heat losses per m^2 from the swimming pool was the lowest at 6 AM and then increased to its peak at 2 PM. It follows a trend similar to the evaporative losses. This is because, in an open swimming pool, the major contributor to the heat losses is evaporation.
- The study of evaporative loss revealed that for a fixed relative humidity, evaporative loss increases with increase in ambient temperature.

- As ambient temperature increases, the saturation vapour pressure of water increases and so does the partial pressure of water vapour.
- The nature of the plots obtained, imply that the rate of increase in saturation pressure is higher than the rate of increase in partial pressure for a unit increase in ambient temperature.
- It was also observed that the slope of the curves obtained decreased with increase in relative humidity.
- The highest value of evaporative loss (654.81 W/m^2) was for the highest ambient temperature(30°C) and least relative humidity condition(5%).

CHAPTER 6

CONCLUSIONS

In the present investigation, water temperature of NIT Rourkela's swimming pool and ambient air temperature were recorded for 26 days from 2 Nov 2010 to 27 Nov 2010, 6 times a day on a regular basis. Based on the available relative humidity and water vapour pressure data, respective heat losses from the swimming pool per unit area were calculated for 5 days from 23 Nov 2010 to 27 Nov 2010. Graph plots were made for the obtained results of evaporative heat losses per unit area and total heat losses per unit area of the swimming pool for the concerned duration of 5 days. The results were interpreted and discussed.

A study on evaporative heat loss from the swimming pool was carried out using MATLAB and it was found to increase with an increase in ambient air temperature at a constant relative humidity. Also, the slope of the curve decreased with an increase in relative humidity.

CHAPTER 7
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